

Coal

Although coal use is expected to be displaced by natural gas in some parts of the world, only a slight drop in its share of total energy consumption is projected by 2025. Coal continues to dominate electricity and industrial sector fuel markets in emerging Asia.

In the *International Energy Outlook 2005* (IEO2005) reference case, world coal consumption is projected to increase from 5,262 million short tons⁵ in 2002 to 7,245 million tons in 2015, at an average rate of 2.5 percent per year. From 2015 to 2025, the projected rate of increase in world coal consumption slows to 1.3 percent annually, and total consumption in 2025 is projected at 8,226 million tons (Figure 50). World GDP and primary energy consumption also are projected to grow at a more rapid pace during the first half than during the second half of the forecast period, reflecting a gradual slowdown in growth of the economies of emerging Asia, which currently are expanding at a rapid pace.

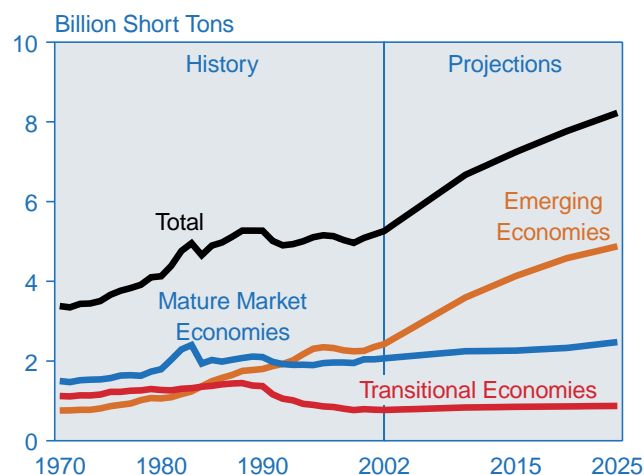
Coal consumption in 2002—primarily in the electric power and industrial sectors—accounted for 24 percent of total world energy consumption (Figure 51). Of the coal produced worldwide, 65 percent was shipped to electricity producers, 31 percent to industrial consumers, and most of the remaining 4 percent to coal consumers in the residential and commercial sectors. In the industrial sector coal is an important input for the manufacture of steel and for the production of steam and

direct heat for other industrial applications. Coal plays a limited role in the residential and commercial sectors, and although it was once an important fuel for transportation, its use for transportation is now virtually nonexistent.

Coal's share of world energy consumption in the electricity and industrial sectors is projected to remain relatively stable in the *IEO2005* forecast. As a consequence, its share of total world energy consumption remains near its 2002 share of 24 percent. In the electricity sector, coal's share of energy consumption is projected to decline slightly, from 39 percent in 2002 to 38 percent in 2025. In the industrial sector, its share is projected to rise from 20 percent in 2002 to 22 percent in 2015 and to remain at that level through 2025.

To a large extent, the slight increase in the importance of coal in the industrial sector results from the substantial growth projected for industrial energy consumption in China, which has abundant coal reserves, limited reserves of oil and natural gas, and a dominant position in world steel production. Coal is expected to remain the

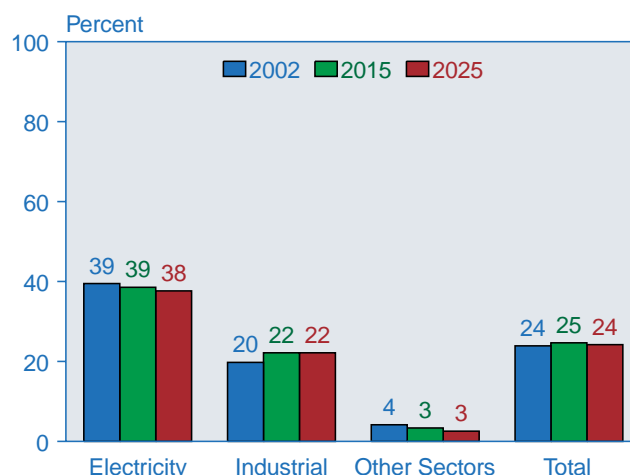
Figure 50. World Coal Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, System for the Analysis of Global Energy Markets (2005).

⁵Throughout this chapter, tons refers to short tons (2,000 pounds).

Figure 51. Coal Share of World Energy Consumption by Sector, 2002, 2015, and 2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **2015 and 2025:** EIA, System for the Analysis of Global Energy Markets (2005).

fuel of choice in China's rapidly expanding industrial sector. In the IEO2005 reference case forecast, the coal share of China's industrial energy consumption increases from 50 percent in 2002 to 55 percent in 2025. In the rest of the world, coal's share of industrial energy consumption is projected to decline from 15 percent in 2002 to 13 percent in 2025.

International coal trade is projected to increase from 714 million tons in 2003 to 969 million tons in 2025, accounting for approximately 12 to 13 percent of total world coal consumption over the period. Steam coal (including coal for pulverized coal injection at blast furnaces) accounts for most of the projected increase in world coal trade. Details of recent changes in international coal markets and an assessment of the long-term outlook for world coal trade are provided at the end of this chapter.

Reserves

Total recoverable reserves of coal⁶ around the world are estimated at 1,001 billion tons—enough to last approximately 190 years⁷ at current consumption levels (Figure 52). Historically, estimates of world recoverable coal reserves, although relatively stable, have declined gradually from 1,167 billion tons at the beginning of 1990 to 1,083 billion tons in 2000 and 1,001 billion tons in 2003 [1]. The most recent assessment of world coal reserves includes a substantial downward adjustment for Germany, from 73 billion tons of recoverable coal reserves to 7 billion tons. The reassessment primarily reflects more

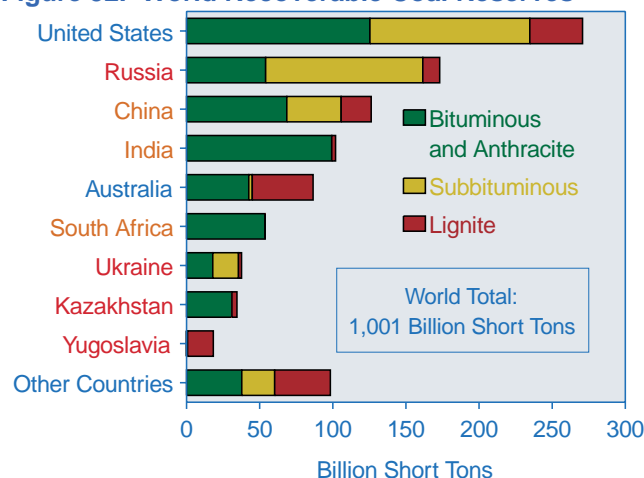
restrictive criteria for the depth and thickness parameters associated with both underground and surface minable seams of coal [2].

Although coal deposits are widely distributed, 57 percent of the world's recoverable reserves are located in three countries: the United States (27 percent), Russia (17 percent), and China (13 percent). Another six countries—India, Australia, South Africa, Ukraine, Kazakhstan, and Yugoslavia—account for an additional 33 percent. In 2002, these nine countries, taken together, accounted for 90 percent of the world's estimated recoverable coal reserves and 78 percent of total world coal production [3]. By rank, bituminous and anthracite coal account for 53 percent of the world's estimated recoverable coal reserves (on a tonnage basis), subbituminous coal accounts for 30 percent, and lignite accounts for 17 percent.

Quality and geological characteristics of coal deposits are important parameters for coal reserves. Coal is a heterogeneous source of energy, with quality (e.g., characteristics such as heat, sulfur, and ash content) varying significantly from one region to the next and even within an individual coal seam. At the top end of the quality spectrum are premium-grade bituminous coals that are used to manufacture coke for the steelmaking process. Coking coals produced in the United States have an estimated heat content of 27.4 million Btu per ton and a relatively low sulfur content of approximately 0.8 percent by weight [4]. At the other end of the spectrum are reserves of low-Btu lignite or "brown coal." On a Btu basis, lignite reserves show considerable variation. Estimates published by the International Energy Agency indicate that the average heat content of lignite for major producing countries varies from a low of 4.6 million Btu per ton in Greece to a high of 12.3 million Btu per ton in Canada in 2002 [5].

A potential new entrant as a producer of lignite is Pakistan, where interest has been sparked by the identification of a huge lignite resource in the Tharparkar (Thar) Desert in the 1990s. The Thar coalfield covers an area of approximately 3,500 square miles and is estimated to contain 193 billion tons of lignite resources [6]. Four tracks of the Thar coalfield currently undergoing more detailed assessment, comprising an area of about 138 square miles, are estimated to contain 3 billion tons of recoverable coal reserves. This represents 89 percent of Pakistan's total recoverable reserves, as published by the World Energy Council [7]. Analyses of Thar lignite indicate a relatively high heat content, between 9.4 and 12.7 million Btu per ton [8]. The Pakistan government currently is working with two international companies,

Figure 52. World Recoverable Coal Reserves



Note: Data for the United States represent recoverable coal estimates as of January 1, 2004. Data for other countries are as of January 1, 2003.

Source: Energy Information Administration, *International Energy Annual 2003*, DOE/EIA-0219(2003) (Washington, DC, June 2005), Table 8.2, web site www.eia.doe.gov/iea/.

⁶Recoverable reserves are those quantities of coal which geological and engineering information indicates with reasonable certainty can be extracted in the future under existing economic and operating conditions.

⁷Assuming that world coal consumption continues to increase at the same rate as is projected for the years 2015 through 2025 (1.3 percent per year), current estimated world coal reserves would last for only about 90 years.

the Shenhua Group and AES Corporation, toward the development of several minemouth power plants in the Thar coalfield [9].

Regional Demand Forecasts

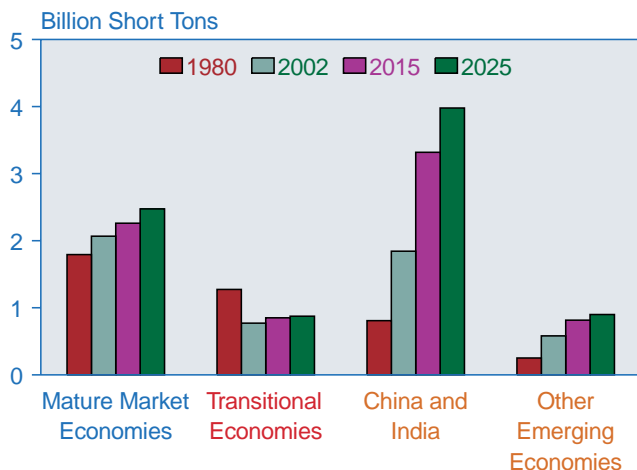
Mature Market Economies

Coal consumption in the mature market economies is projected to rise at a relatively even pace over the forecast horizon, from 2,067 million tons in 2002 to 2,261 million tons in 2015 and 2,474 million tons in 2025 (Figure 53). Much of the 407-million-ton increase in coal consumption projected for the mature market economies over the forecast period is the result of expected strong growth in U.S. coal demand. While modest increases in coal consumption are projected for Canada and Australia/New Zealand, coal consumption in Western Europe is projected to decline by 114 million tons between 2002 and 2025. In Western Europe, natural gas and renewable energy are projected to capture an increasing share of the region's total energy consumption, displacing both coal and nuclear energy.

North America

Coal use in North America is dominated by U.S. consumption. In 2002, the United States consumed 1,066 million tons, accounting for 93 percent of the regional total. U.S. consumption is projected to rise to 1,505 million tons in 2025. The United States has substantial coal reserves and has come to rely heavily on coal for electricity generation, a trend that continues in the forecast. Coal's share of total U.S. electricity generation is projected to decline slightly from 52 percent in 2002 to 51 percent in 2015 and then return to 53 percent in 2025 [10].

Figure 53. World Coal Consumption by Region, 1980, 2002, 2015, and 2025



Sources: **1980 and 2002:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219 (2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **2015 and 2025:** EIA, *System for the Analysis of Global Energy Markets* (2005).

To a large extent, the projections of increasing prices for natural gas after 2010, combined with projections of relatively stable minemouth coal prices and slightly declining rates for domestic transportation of coal, are the key factors helping coal compete as a fuel for U.S. power generation. Increases in coal-fired generation are projected to result from both greater utilization of existing U.S. coal-fired generating capacity and an additional 89,500 megawatts of new coal-fired capacity by 2025 (3,600 megawatts of older coal-fired capacity is projected to be retired). The average utilization rate of coal-fired generating capacity is projected to rise from 70 percent in 2002 to 83 percent in 2025.

In Canada, coal's share of total energy consumption is projected to decline slightly over the forecast period, from 13 percent in 2002 to 12 percent in 2025. In the near term, the restart of four of Canada's nuclear generating units after 2002 is expected to restrain the need for coal in eastern Canada. Between September 2003 and January 2004, three of the four units, representing 2,000 megawatts of generating capacity, were returned to service—Unit 4 at the Ontario Power Generation (OPG) Pickering A plant and Units 3 and 4 at Bruce Power's Bruce A plant [11]. OPG's 500-megawatt Unit 1 at the Pickering A plant is scheduled to come back on line in late 2005.

In 2004, coal-fired generation accounted for 17 percent of Ontario's electricity supply, down from 23 percent in 2003, and its share could decline further in the future [12]. The Ontario government currently plans to shut down all of the Province's 7,560 megawatts of coal-fired generating capacity by early 2009, although the government has indicated that the shutdowns will not occur unless generation from alternative sources can be secured [13]. The decision is based primarily on the premise that the adverse health and environmental impacts of the plants' operation are unacceptable. In western Canada, increasing demand for electricity is expected to result in the need for additional coal-fired generating capacity, primarily in Alberta.

Mexico consumed 14 million tons of coal in 2002. In 2025 it is projected to consume 25 million tons. Two coal-fired generating plants, Rio Escondido (1,200 megawatts) and Carbon II (1,400 megawatts), operated by the state-owned utility Comisión Federal de Electricidad (CFE), consume approximately 10 million tons of coal annually, most of which comes from domestic mines [14]. In addition, CFE has recently switched its six-unit, 2,100-megawatt Petacalco plant, located on the Pacific coast, from oil to coal. Petacalco's estimated annual coal consumption is 6 million tons of imported coal, although CFE has maintained the option to generate with fuel oil. The utility plans to add an additional 700 megawatts of coal-fired capacity at the Petacalco plant late in the decade [15].

Western Europe

In Western Europe, environmental concerns play an important role in the competition among coal, natural gas, and nuclear power. Recently, other fuels—particularly, natural gas—have been gaining relative to coal in the generation market. Coal consumption in Western Europe has fallen by 36 percent since 1990, from 894 million tons to 573 million tons in 2002. The decline was smaller on a Btu basis, at 30 percent, reflecting the fact that much of it resulted from reduced consumption of low-Btu lignite in Germany.

Over the forecast period, coal consumption in Western Europe is projected to fall by an additional 20 percent (on a tonnage basis), reflecting a slower rate of decline than during the previous decade. Factors contributing to further cutbacks in coal consumption include continued penetration of natural gas for electricity generation, growing use of renewable fuels in the region, continuing pressure on member countries of the European Union to reduce subsidies that support domestic production of hard coal,⁸ and relatively slow growth in overall energy consumption (0.5 percent per year). Despite a considerable drop in lignite consumption since 1990, this low-rank fuel continues to be an important component of the Western European coal market. In 2002, lignite accounted for 50 percent of the region's total coal consumption on a tonnage basis and 29 percent on a Btu basis [16].

Coal consumption in Western Europe's electric power sector is projected to decline from 6.4 quadrillion Btu in 2002 to 5.4 quadrillion Btu in 2015 and 4.8 quadrillion Btu in 2025. Germany is currently the leading coal-consuming country in Western Europe, a position it is expected to maintain over the forecast period. Much of the planned and recently completed work on coal-fired generating capacity in Western Europe is related to either the replacement or refurbishment of existing capacity. Germany, Spain, France, Italy, and Greece all are planning major projects to upgrade existing coal-fired generating facilities over the next two decades.

Mature Market Asia

Mature market Asia consists of Australia, New Zealand, and Japan. Australia is the world's leading coal exporter, and Japan is the world's leading coal importer. In 2002, Australian coal producers shipped 225 million tons of coal to international consumers and consumed another 160 million tons (both hard coal and lignite) domestically, primarily for electricity generation. Coal-fired power plants accounted for 78 percent of Australia's total electricity generation in 2002, a level that is projected to be maintained over the forecast horizon [17]. Overall coal use for Australia and New Zealand, taken

together, is projected to increase by 47 million tons (29 percent), from 162 million tons in 2002 to 209 million tons in 2025. The most recent energy forecast released by the Australian government (August 2004) indicates that coal consumption in Australia will increase by 1.5 percent per year on a Btu basis from 2002 to 2020, which is slightly higher than the projected rate of 1.4 percent for Australia/New Zealand over the same period in the *IEO2005* reference case [18].

Japan, which is the seventh largest coal user globally (following China, India, the United States, Russia, Germany, and South Africa), imports nearly all the coal it consumes, much of it originating from Australia [19]. Currently, about 44 percent of the coal consumed in Japan is used by the country's steel industry (Japan is the world's second largest producer of both crude steel and pig iron, behind China) [20]. Coal is also used heavily in the Japanese power sector, and coal-fired plants generated 27 percent of the country's electricity supply in 2002 [21]. During the years 2001 through 2004, 8,700 megawatts of new coal-fired generating capacity was brought on line in Japan [22]. Additional coal-fired generating capacity originally scheduled to come on line between the end of 2004 and the end of 2008 has been postponed to later dates [23]. In the *IEO2005* forecast, increased use of other fuels for electricity generation (including natural gas, renewables, and nuclear), coupled with an outlook for slow economic growth and a decline in population, results in a relatively flat outlook for Japanese coal consumption.

Transitional Economies

Coal consumption in the transitional economies of Eastern Europe and the former Soviet Union (EE/FSU) is projected to rise over the forecast horizon from 771 million tons in 2002 to 850 million tons in 2015 and 874 million tons in 2025. In the EE/FSU countries, the process of economic reform and the transition to market-oriented economies from centrally planned economic systems continue to advance. The dislocations associated with institutional changes in the region have contributed substantially to declines in both production and consumption of coal. In 2002, coal consumption in the EE/FSU region was 44 percent lower (on a tonnage basis) than in 1990. In the *IEO2005* reference case, coal's share of total EE/FSU energy consumption is projected to decline from 22 percent in 2002 to 17 percent in 2025 (Figure 54). During this same period, natural gas' share of total energy consumption is projected to increase from 45 percent to 51 percent.

Substantial declines in economic output and energy demand following the breakup of the Soviet Union in 1991 led to considerable declines in both overall energy

⁸Internationally, the term "hard coal" is used to describe anthracite and bituminous coal. In data published by the International Energy Agency, coal of subbituminous rank is classified as hard coal for some countries and as brown coal (with lignite) for others.

consumption and coal consumption in the FSU. In 2002, total energy consumption in the FSU was 18.5 quadrillion Btu, or 30 percent, below the level in 1990, and coal consumption was down by 6.0 quadrillion Btu, or 45 percent. Reversing recent historical trends, coal consumption in Russia and the other FSU countries is projected to increase over the forecast period. Russia's coal consumption is projected to increase by 59 million tons (26 percent) from 2002 to 2025, and consumption in other FSU countries is projected to rise by 24 million tons (15 percent).

Of the 15 FSU countries, Russia, Ukraine, and Kazakhstan together account for virtually all the coal consumption and production in the region, and this is expected to remain the case in the future [24]. The *IEO2005* outlook for Russia's coal consumption is generally consistent with the long-term energy policy set forth in the August 2003 document, *Russia's Energy Strategy for the Period up to 2020* [25]. Although Russia's long-term energy strategy favors a considerable amount of new nuclear generating capacity, fossil-fuel-fired plants are expected to continue in their role as the primary source for electric power generation through 2020. For new fossil-fired generating capacity, Russia's energy strategy promotes the construction of advanced coal-fired generating capacity in the coal-rich Siberian region (central Russia) and recommends a focus on efficient natural-gas-fired capacity for the western and far eastern areas of the country. Coal consumption in other FSU countries is projected to increase slightly, primarily as the result of increased utilization of existing coal-fired generating capacity in Kazakhstan and Ukraine.

In Eastern Europe, coal consumption is projected to increase slightly over the forecast period, from 374 million tons in 2002 to 394 million tons in 2025. Poland is the region's largest producer and consumer of coal and the second largest coal producer and consumer in all of Europe, outranked only by Germany [26]. In 2002, coal consumption in Poland totaled 149 million tons—40 percent of Eastern Europe's total coal consumption for the year. The most recent (January 2005) long-term energy policy put forth by the Polish government indicates that coal-fired generation should remain relatively constant, with new natural-gas-fired capacity used to meet future demand in the electricity sector [27]. Additional plans for both new coal-fired capacity and the refurbishment of existing capacity in other Eastern European countries, including Bosnia and Herzegovina, Bulgaria, the Czech Republic, Macedonia, Slovakia, and Yugoslavia, is a strong indicator that coal will continue to be an important source of energy in the region [28].

Emerging Asia

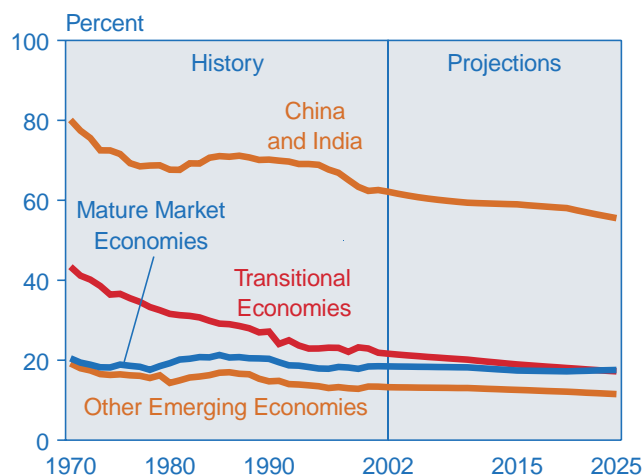
Coal consumption in the emerging economies of Asia is projected to more than double in the *IEO2005* reference case forecast, increasing from 2,118 million tons in 2002 to 3,715 million tons in 2015 and 4,435 million tons in 2025. The projected increase of 2,317 million tons from 2002 to 2025 represents 78 percent of the increase in worldwide coal consumption over the period. With substantial growth in coal consumption in China (1,819 million tons) and India (315 million tons) over the forecast period, emerging Asia's share of total world coal consumption is projected to rise from 40 percent in 2002 to 51 percent in 2015 and 54 percent in 2025.

Despite the tremendous increases in coal consumption projected for emerging Asia, coal's share of total energy consumption in the region is still projected to decline slightly, from 47 percent in 2002 to 44 percent in 2025. Much of the decline in coal's share is attributed to fast-paced growth projected for natural gas use in the region.

As very large countries (in terms of both population and landmass) with large domestic coal resources, China and India account for 71 percent of the total increase in coal use worldwide (on a Btu basis) over the forecast period; however, coal's share of energy use in China and India, and in emerging Asia as a whole, still is projected to decline. The large increases in coal consumption projected for China and India are based on an outlook for strong economic growth (averaging 6.2 percent per year in China and 5.5 percent per year in India from 2002 to 2025) and the expectation that much of the increased demand for energy will be met by coal, particularly in the industrial and electricity sectors.

In China's electricity sector, coal use is projected to grow by 3.3 percent a year, from 14.8 quadrillion Btu in 2002 to

Figure 54. Coal Share of Total Energy Consumption by Region, 1970-2025



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **Projections:** EIA, *System for the Analysis of Global Energy Markets* (2005).

31.2 quadrillion Btu in 2025 (Figure 55). In comparison, coal consumption by electricity generators in the United States is projected to rise by 1.6 percent annually, from 19.8 quadrillion Btu in 2002 to 28.6 quadrillion Btu in 2025. One of the key implications of the substantial rise in coal use for electricity generation in China is that large financial investments in new coal-fired power plants and in the associated transmission and distribution systems will be needed. The projected growth in electricity sector coal demand for China would result in the need for 229,000 megawatts of additional coal-fired capacity (net of retirements) by 2025 [29]. At the end of 2002, China had an estimated 204,000 megawatts of coal-fired generating capacity.

In 2002, 47 percent of China's coal use was in the non-electricity sectors, primarily in the industrial sector. Over the forecast period, coal demand in China's non-electricity sectors is expected to increase by 19.4 quadrillion Btu (148 percent), raising the non-electricity share of total coal demand to 51 percent in 2025. Coal remains the primary source of energy in China's industrial sector, primarily because China has limited reserves of oil and natural gas. In 2002, China was the world's leading producer of both steel and pig iron [30].

With a substantial portion of the increase in China's demand for both oil and natural gas projected to be met by imports, the Chinese government is actively promoting the development of a large coal-to-liquids industry. Initial production of coal-based synthetic liquids in China is scheduled to commence in mid-2007 with the completion of the country's first coal-to-liquids plant. The plant, located in the Inner Mongolia Autonomous

Region, is being built by the Shenhua Coal Liquefaction Corporation. Following the completion of a second production phase at the same site in 2010, the facility will be capable of converting approximately 17 million tons of coal to 37 million barrels of petroleum products annually (approximately 100,000 barrels per day) [31]. The Shenhua Coal Liquefaction Corporation plans to expand production of coal-based synthetic liquids to about 220 million barrels per year (approximately 600,000 barrels per day) in 2020, requiring an estimated 80 to 100 million tons of coal per year as an input [32].

In India, slightly less than 60 percent of the projected growth in coal consumption is attributable to increased demand for coal in the electricity sector, and the industrial sector accounts for most of the remaining increase. In 2002, electricity generation accounted for 67 percent of India's total coal use. The use of coal for electricity generation in India is projected to rise by 2.2 percent per year, from 5.1 quadrillion Btu in 2002 to 8.5 quadrillion Btu in 2025, requiring an additional 59,000 megawatts of coal-fired capacity (net of retirements) [33]. At the end of 2002, India had an estimated 66,000 megawatts of coal-fired generating capacity. Currently, the government is targeting the construction of approximately 40,000 megawatts of new coal-fired generating capacity for the country over the 10-year period ending March 2012 [34].

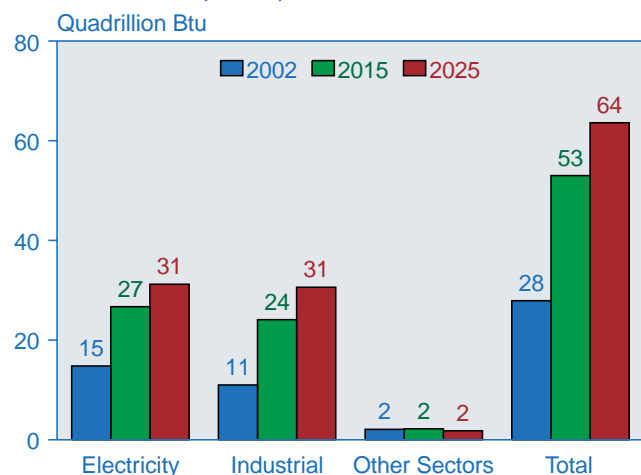
In the other areas of emerging Asia, a considerably smaller rise in coal consumption is projected over the forecast period, based on expectations for growth in coal-fired electricity generation in South Korea, Taiwan, and the member countries of the Association of South-east Asian Nations (primarily Indonesia, Malaysia, the Philippines, Thailand, and Vietnam). In the electricity sector, coal use in the other emerging countries of Asia (including South Korea) is projected to increase by 2.6 percent per year, from 2.9 quadrillion Btu in 2002 to 5.2 quadrillion Btu in 2025.

The key motivation for increasing use of coal in other emerging Asia is to maintain a diversity of fuel supply for electricity generation. This objective is shared even in countries that have abundant reserves of natural gas, such as Thailand, Malaysia, Indonesia, and the Philippines. In the *IEO2005* forecast, coal's share of fuel consumption for electricity generation in the region (including South Korea) is projected to increase from 27 percent in 2002 to 30 percent in 2015, then decline to 26 percent in 2025 as consumption of natural gas for electricity generation increases.

Middle East

In 2002, Middle Eastern countries consumed 84 million tons of coal, with Turkey accounting for more than 86 percent of the total. Most of the coal consumed in Turkey is locally produced, low-Btu lignite [35]. Israel accounts for most of the region's remaining coal consumption.

Figure 55. Coal Consumption in China by Sector, 2002, 2015, and 2025



Sources: **2002:** Derived from Energy Information Administration (EIA), *International Energy Annual 2002*, DOE/EIA-0219(2002) (Washington, DC, March 2004), web site www.eia.doe.gov/iea/. **2015 and 2025:** EIA, *System for the Analysis of Global Energy Markets* (2005).

Over the forecast period, coal consumption in the Middle East is projected to increase by 32 million tons.

Much of the increased use of coal projected for the Middle East is for electricity generation. In Turkey, the completion of two new coal-fired power plants in 2003 and 2005 is projected to add an additional 23 million tons to the country's annual coal consumption. The projects consist of a 1,300-megawatt hard-coal-fired plant being built on the southern coast of Turkey near Iskenderun, to be fueled by imported coal, and a 1,440-megawatt lignite-fired plant (Afsin-Elbistan B plant) being built in the lignite-rich Afsin-Elbistan region in southern Turkey [36]. Because of the extremely low heat content of the indigenous lignite feedstock for the Afsin-Elbistan B plant—approximately 4.0 million Btu per ton—annual fuel requirements are estimated to be 19 million tons [37]. In Israel, state-owned Israel Electric Corporation plans to bring an additional 1,100 megawatts of coal-fired generating capacity on line at Ashkelon in 2012, near the site of its 2,250-megawatt Rutenberg coal plant [38].

Africa

Africa's coal consumption is projected to increase by 81 million tons between 2002 and 2025, primarily to meet demand for electricity, which is projected to increase at a rate of 3.7 percent per year. South Africa currently accounts for 92 percent of the coal consumed in the continent and is expected to continue to account for much of the increase in Africa's total coal consumption over the forecast period. Additional growth in coal consumption is likely to occur in some of the other countries of southern Africa that also are well endowed with indigenous coal resources.

In South Africa, increasing demand for electricity in recent years has led to the decision by Eskom, the country's state-owned electricity supplier, to restart three large coal-fired plants (Camden, Grootvlei, and Komati) that have been closed for more than a decade [39]. The first of the three plants is scheduled to come back on line in 2005, and the remaining plants are scheduled for restart in 2008. The plants have a combined generating capacity of 3,800 megawatts [40]. Projections of power shortages for southern Africa in the latter half of this decade have led to increased interest in new coal-fired power projects not only in South Africa but also in Zimbabwe, Tanzania, Swaziland, and Botswana [41].

Central and South America

Historically, coal has not been a major source of energy in Central and South America. In 2002, coal accounted for about 4 percent of the region's total energy consumption, and in past years its share has never exceeded 5 percent. In the electricity sector, hydroelectric power has met much of the region's electricity demand, and new power plants are now being built to use natural gas

produced in the region. Over the forecast period, a combination of fuels—natural gas, oil, and renewable energy (including hydropower and other renewables)—is expected to fuel most of the region's projected increase in electricity generation. In the *IEO2005* reference case, coal is projected to maintain a 4-percent share of Central and South America's total primary energy consumption.

Brazil, with the world's eighth largest steel industry in 2002, accounted for more than 62 percent of the region's coal demand (on a tonnage basis); Colombia, Chile, Argentina, Peru, and Venezuela accounted for much of the remainder [42]. In the forecast, Brazil accounts for most of the growth in coal consumption projected for the region, with increased use of coal expected for both steelmaking and electricity production. Brazil's steel companies currently plan to expand production capacity by a substantial amount over the next few years to meet increasing domestic and international demand for steel [43]. Brazil's three southernmost States, Rio Grande do Sul, Santa Catarina, and Parana, which contain most of the country's coal reserves, are actively promoting the construction of several new coal-fired power plants [44]. The new coal projects being promoted by the government of Rio Grande do Sul represent a key component of its plan to become self-sufficient in electricity supply.

Trade

Overview

Compared with world coal consumption, the amount of coal traded in international markets is relatively small. In 2003, world imports of coal amounted to 714 million tons (Figure 56 and Table 9), representing 13 percent of total world consumption. In 2025, coal imports worldwide are projected to total 969 million tons, or 12 percent of world coal consumption.

The world coal market consists of essentially two distinct markets—a steam coal market and a coking coal market. The international steam coal market consists largely of (1) demand for coal for electricity generation, (2) demand for coal to produce steam and direct heat for industrial applications, and (3) demand for coal to be used in blast furnaces for steelmaking. The international market for coking coal consists solely of demand for coal coke as a fuel and reducing agent for smelting iron ore in blast furnaces.

Growth in international coal trade in recent years has resulted primarily from increased demand for steam coal for electricity generation, particularly in Asia. In contrast, the world market for coking coal has been relatively stable, as Asian steel producers have increased their imports and Europe and the Americas have decreased imports. Most recently, increased imports of coking coal by China in 2003 and 2004 have contributed to the upward trend for coking coal imports to Asia.

Two factors that have contributed to the relatively flat trend in world coking coal imports are continuing increases in steel production from electric arc furnaces (which do not use coal coke as an input), primarily in Europe and North America; and technological improvements at blast furnaces, including greater use of pulverized coal injection and higher average injection rates per ton of hot metal produced [45].

In the *IEO2005* forecast, world steam coal trade is projected to increase by 1.5 percent per year, from 504 million tons in 2003 to 693 million tons in 2025. Increased exports to Asia, primarily to fuel new coal-fired generating capacity, account for most of the projected expansion in the world steam coal market. World coking coal trade is projected to increase by 1.3 percent per year, from 210 million tons in 2003 to 276 million tons in 2025. Increased imports of coking coal are projected for China, South Korea, Taiwan, India, and Brazil, where expansions in blast-furnace-based steel production are expected.

Asia

Based primarily on strong growth in electricity demand, Asia's demand for imported coal remains poised for additional increases over the forecast period (Figure 57). In the *IEO2005* forecast, South Korea, Taiwan, India, China, and Malaysia are projected to account for most of the projected growth in coal imports to Asia.

Although Japan's share of total world coal trade has been declining, it continues to be the world's leading importer of coal and is projected to account for 19 percent of total world imports in 2025, less than its 2003 share of 25 percent [46]. In 2003, Japan relied almost entirely on imported coal for domestic consumption, purchasing 182 million tons of coal from foreign suppliers. In *IEO2005*, expectations of slow economic growth (1.7 percent per year from 2002 to 2025) and a shift to a less energy-intensive economy lead to relatively small changes in Japan's total energy consumption (average annual growth of 0.5 percent) and virtually no change in coal consumption. As a result, Japan's coal imports are projected to remain near the 2003 level throughout the forecast. Japan's share of total Asian coal imports, which declined from 85 percent in 1980 to 46 percent in 2003 primarily as a result of increases in coal imports by South Korea, Taiwan, and India, is projected to continue falling to 29 percent in 2025.

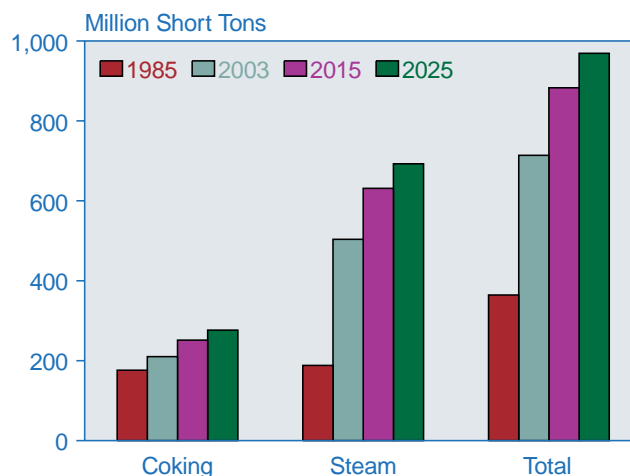
South Korea, currently the second leading importer of coal worldwide, is expected to maintain that position over the forecast period. Coal imports to South Korea are projected to increase from 77 million tons in 2003 to 143 million tons in 2025. As a result, South Korea's share of Asian coal imports is projected to rise from 19 percent in 2003 to 22 percent in 2025. From 2004 through 2010, South Korean electricity generators plan to add more

than 8,000 megawatts of new coal-fired generating capacity [47].

China and India, which import relatively small quantities of coal at present, are expected to account for much of the remaining increase in coal imports projected for Asia. From 2003 to 2025, coal imports by China and India, taken together, are projected to increase by 109 million tons. Increased imports of coking coal account for approximately half of the overall increase in coal imports projected for China and India, which is unlike the outlook for other Asian countries, where fuel requirements for new coal-fired power plants are the key source of coal demand. Imports by China and India have the potential to be even higher than projected, but it is assumed in the forecast that domestic coal will be given first priority in meeting the large projected increase (2.1 billion tons) in coal consumption in the two countries.

Elsewhere in Asia, recent and planned additions of coal-fired capacity have increased and will continue to add to coal import demand in the region. In both Malaysia and Taiwan, coal imports are projected to rise substantially over the forecast period to fuel new coal-fired power plants. Diversification of fuel supply for electricity generation is the key factor underlying Malaysia's plans for additional coal-fired generating capacity [48]. Taiwan Power cites cost advantages over natural-gas- and oil-fired plants as the key factor underlying its plans for new coal plants [49]. In Thailand, the 1,434-megawatt

Figure 56. World Coal Trade, 1985, 2003, 2015, and 2025



Sources: **1985:** Energy Information Administration (EIA), *Annual Prospects for World Coal Trade 1987*, DOE/EIA-0363(87) (Washington, DC, May 1987). **2003:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 14, No. 2 (London, UK, May 2005); and Energy Information Administration, *Quarterly Coal Report*, October-December 2003, DOE/EIA-0121(2003/4Q) (Washington, DC, March 2004). **2015 and 2025:** Energy Information Administration, National Energy Modeling System run IEO2005.D060605B.

Table 9. World Coal Flows by Importing and Exporting Regions, Reference Case, 2003, 2015, and 2025
(Million Short Tons)

Exporters	Importers											
	Steam				Coking				Total			
	Europe ^a	Asia	Americas	Total ^b	Europe ^a	Asia ^c	Americas	Total ^b	Europe ^a	Asia	Americas	Total ^b
2003												
Australia	12.5	96.1	6.8	115.8	29.0	85.1	8.1	122.3	41.5	181.3	14.9	238.1
United States	3.0	0.2	18.5	21.8	14.0	0.0	7.2	21.2	17.0	0.3	25.7	43.0
South Africa	70.2	5.5	0.4	77.2	1.0	0.0	0.5	1.6	71.2	5.5	1.0	78.7
Former Soviet Union . .	24.2	9.5	0.0	33.8	2.7	4.5	0.0	7.2	26.9	14.0	0.0	41.0
Poland	15.1	0.0	0.0	15.1	1.3	0.0	0.0	1.3	16.4	0.0	0.0	16.4
Canada	0.0	0.9	0.7	1.5	8.1	13.9	4.1	26.2	8.1	14.7	4.7	27.7
China	6.2	81.2	1.1	89.0	0.1	12.6	1.8	14.4	6.3	93.8	2.8	103.4
South America ^d	32.5	0.0	25.2	57.8	0.0	0.0	0.0	0.0	32.5	0.0	25.2	57.8
Indonesia ^e	16.9	70.6	2.9	91.8	0.1	15.8	0.1	16.0	17.0	86.4	3.0	107.8
Total	180.7	263.9	55.6	503.7	56.3	131.9	21.8	210.1	237.0	395.9	77.4	713.9
2015												
Australia	2.5	137.3	0.8	140.7	28.6	121.9	11.9	162.4	31.1	259.2	12.7	303.1
United States	5.9	1.1	4.0	11.0	8.9	0.8	6.5	16.2	14.7	1.8	10.5	27.1
South Africa	56.0	28.8	4.0	88.7	0.9	0.0	0.8	1.7	56.8	28.8	4.8	90.4
Former Soviet Union . .	41.5	23.6	0.0	65.1	3.1	9.4	0.0	12.5	44.6	33.0	0.0	77.5
Poland	6.2	0.0	0.5	6.7	1.1	0.0	0.0	1.1	7.3	0.0	0.5	7.8
Canada	1.5	0.0	0.0	1.5	8.6	15.3	12.7	36.6	10.2	15.3	12.7	38.1
China	0.0	90.4	0.0	90.4	0.0	6.8	0.0	6.8	0.0	97.2	0.0	97.2
South America ^d	53.8	0.0	47.4	101.2	0.0	0.0	0.0	0.0	53.8	0.0	47.4	101.2
Indonesia ^e	13.3	108.3	4.5	126.1	0.0	14.3	0.0	14.3	13.3	122.7	4.5	140.5
Total	180.7	389.5	61.3	631.5	51.1	168.4	31.9	251.5	231.8	558.0	93.2	883.0
2025												
Australia	0.0	164.7	0.8	165.5	29.4	141.1	15.1	185.6	29.4	305.8	15.9	351.2
United States	0.0	1.0	4.1	5.1	6.9	0.0	7.7	14.6	6.9	1.0	11.8	19.7
South Africa	48.0	40.1	4.2	92.3	0.2	0.0	0.9	1.1	48.2	40.1	5.1	93.4
Former Soviet Union . .	42.0	26.5	0.0	68.5	4.2	9.9	0.0	14.1	46.2	36.4	0.0	82.6
Poland	4.4	0.0	0.0	4.4	0.6	0.0	0.0	0.6	5.0	0.0	0.0	5.0
Canada	0.0	0.0	0.0	0.0	9.5	18.5	10.8	38.8	9.5	18.5	10.8	38.8
China	0.0	93.7	0.0	93.7	0.0	7.4	0.0	7.4	0.0	101.1	0.0	101.1
South America ^d	69.4	0.0	56.6	126.0	0.0	0.0	0.0	0.0	69.4	0.0	56.6	126.0
Indonesia ^e	6.3	124.8	6.3	137.3	0.0	14.3	0.0	14.3	6.3	139.1	6.3	151.6
Total	170.1	450.7	72.0	692.8	50.8	191.2	34.4	276.5	220.9	641.9	106.5	969.2

^aCoal flows to Europe include shipments to the Middle East and Africa. In 2003, coal imports to the Middle East and Africa totaled 40.2 million tons.

^bIn 2003, total world coal flows include a balancing item used to reconcile discrepancies between reported exports and imports. The 2003 balancing items by coal type were 3.5 million tons (steam coal), 0.1 million tons (coking coal), and 3.6 million tons (total).

^cIncludes 14.3 million tons of coal for pulverized coal injection at blast furnaces shipped to Japanese steelmakers in 2003.

^dCoal exports from South America are projected to originate from mines in Colombia and Venezuela.

^eIn 2003, coal exports from Indonesia include shipments from other countries not modeled for the forecast period. The 2003 non-Indonesian exports by coal type were 8.4 million tons (steam coal), 1.7 million tons (coking coal), and 10.0 million tons (total).

Notes: Data exclude non-seaborne shipments of coal to Europe and Asia. Totals may not equal sum of components due to independent rounding. The sum of the columns may not equal the total, because the total includes a balancing item between importers' and exporters' data.

Sources: **2003:** SSS Consultancy and Research, Ltd., *SSS's Coal Trade Forecast*, Vol. 14, No. 2 (London, UK, May 2005); and Energy Information Administration, *Quarterly Coal Report*, October-December 2003, DOE/EIA-0121(2003/4Q) (Washington, DC, March 2004). **2015 and 2025:** Energy Information Administration, National Energy Modeling System run IEO2005.D060605B.

Map Ta Phut plant is scheduled to be fully operational in early 2007 [50].

During the 1980s, Australia became the leading coal exporter in the world, primarily by meeting increased demand for steam coal in Asia. Exports of Australian coking coal also increased, as countries such as Japan began using some of Australia's semi-soft or weak coking coals⁹ in their coke oven blends. As a result, imports of hard coking coals from other countries, including the United States, were displaced. Australia's share of total world coal trade, which increased from 17 percent in 1980 [51] to 33 percent in 2003, is projected to remain relatively steady over the forecast period, accounting for 36 percent of total trade in 2025. Australia is expected to continue as the major exporter to Asia, with its share of the region's total coal import demand projected to increase from 46 percent in 2003 to 48 percent in 2025 (Table 9).

Two other major suppliers of coal to Asian markets are China and Indonesia. In 2003, China exported 94 million tons of coal to other Asian countries, representing 24 percent of total Asian coal imports, and Indonesian producers exported 78 million tons to Asia, or 20 percent of the region's total imports for the year. Over the forecast period, increasing domestic demand for coal in both China and Indonesia is projected to limit growth in their coal exports.

The United States, once a major supplier of coal to Asia, is currently only a minor participant in the Asian market. The U.S. share of Asia's coal imports declined from 28 percent in 1980 to less than 0.1 percent in 2003 [52]. In 2004, however, limited supplies of coking coal in the international market and a weaker U.S. dollar led to renewed interest in Appalachian coking coal. U.S. coking coal exports to Asia, which declined from a peak of more than 24 million tons in 1982 to virtually nothing in 2002 and 2003, were more than 5 million tons in 2004 [53]. U.S. steam coal exports to Asia increased from 0.2 million tons in 2003 to 2.3 million tons in 2004.

Europe, Middle East, and Africa

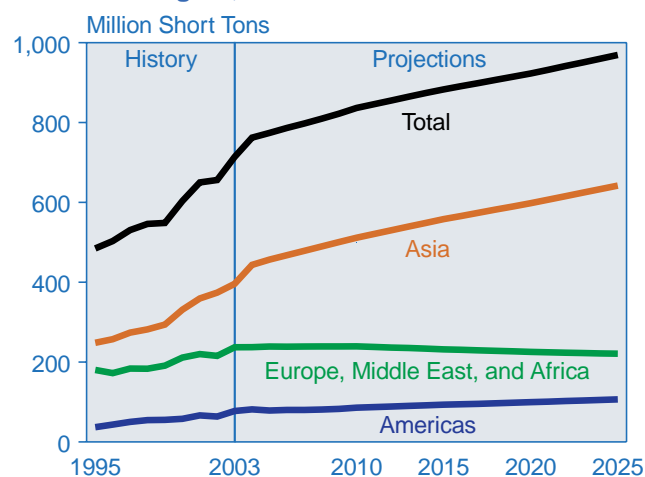
Coal imports to Europe, the Middle East, and Africa, taken as a whole, are projected to increase from 237 million tons in 2003 to 239 million tons in 2010 and then decline to 221 million tons in 2025 (Figure 57 and Table 9). In the IEO2005 forecast, projected declines in overall imports to the countries of Western Europe are partly offset by increases projected for Turkey, Romania, Bulgaria, and Israel.

In Western Europe, environmental pressures and competition from natural gas are expected gradually to

reduce the reliance on steam coal for electricity generation, and further improvements in the steelmaking process are expected to continue to reduce the amount of coal required for steel production. Strict environmental standards are expected to result in the closure of some of Western Europe's older coke plants and to make it difficult to get approvals for plants, thus increasing import requirements for coal coke but reducing imports of coking coal. Projected reductions in domestic coal production in the United Kingdom, Germany, Spain, and France are not expected to be replaced by equivalent volumes of coal imports. Rather, increased use of natural gas and renewable energy is expected to replace much of the reduction in domestic energy supply projected to result from continuing declines in the region's indigenous coal production.

In 2003, the leading suppliers of imported coal to the countries of Europe, the Middle East, and Africa were South Africa (30 percent), Australia (18 percent), South America (14 percent), and the former Soviet Union (11 percent). Over the forecast period, low-cost coal from South America (primarily from Colombia and Venezuela) is projected to meet an increasing share of European coal import demand, displacing some coal from such higher cost suppliers as the United States and Poland.

Figure 57. Coal Imports by Major Importing Region, 1995-2025



Sources: **History:** SSY Consultancy and Research, Ltd., *SSY's Coal Trade Forecast*, Vol. 14, No. 2 (London, UK, May 2005); International Energy Agency, *Coal Information 2001* (Paris, France, September 2001), and previous issues; and Energy Information Administration, *Quarterly Coal Report*, October-December 2003, DOE/EIA-0121(2003/4Q) (Washington, DC, March 2004), and previous issues. **Projections:** Energy Information Administration, National Energy Modeling System run IEO2005.D060605B.

⁹Semi-soft or weak coking coal is blended with hard coking coal before being charged into the coke oven to produce coke. Semi-soft coal needs to be blended because, used alone, it does not produce coke with sufficient strength. Coal coke is used primarily to smelt iron ore in blast furnaces, acting as a source of heat and as a chemical reducing agent for the production of pig iron.

Recent Developments in World Coal Trade

The years 2003 and 2004 saw two solid back-to-back increases in international coal shipments. In 2003, world coal trade rose to 714 million tons, an increase of 9 percent from 2002. Preliminary data for 2004 indicate that world coal trade reached approximately 760 million tons, for an additional increase of 6 percent over 2003.^a Gains in coal shipments to each of the three major coal import demand regions discussed in this chapter contributed to the 100-million-ton-plus increase in world coal trade for the 2-year period.

In addition to the substantial increases in international coal trade in 2003 and 2004, other notable developments for the period were sharp upward movements in both ocean freight rates and coal export prices. During 2003, ocean freight rates for coal rose to near all-time record highs. Much of the increase was attributable to substantial growth in imports of iron ore by Chinese steel producers, which in turn created a shortage of ocean vessels for transporting other dry bulk products, including coal.^b China imported 163 million tons of iron ore in 2003, an increase of 33 percent from 2002.^c According to Global Insight, Inc., substantial amounts of new shipping capacity projected to come on line by the end of 2007 should help to alleviate the current capacity shortage, which in turn should lead to some reductions in freight rates.^d Global Insight estimates that between the beginning of 2004 and the end of 2007 annual dry-bulk-shipping capacity will expand by approximately 550 million tons, while demand for annual dry-bulk-shipping will increase by only 309 million tons.

While freight rates for coal retreated some from the historic highs reached in early 2004, coal export prices (both steam and coking) began increasing in late 2003 and continued to rise throughout 2004. Limited supply of export coal is the primary explanation given for the substantial rise in coal export prices. Some of the factors that restrained export supply during the year included (1) substantial shipping delays at Australian coal ports, as expansions in port infrastructure have not kept pace with the recent surge in China's demand for iron ore and coking coal; (2) reduced exports of

steam coal out of South Africa, mostly due to rail-related shipping delays; and (3) reduced exports and increased imports of coking coal by China. Relative to 2003, China imported an additional 4 million tons of coking coal in 2004 and exported 8 million tons less. Other factors affecting coal export prices in 2003 and 2004 were the effects of higher freight rates on international coal markets, increasing concentration in the ownership of coal export supply, and increasing importance of coal-on-gas competition in international power supply.^e

Taken together, higher freight rates and coal export prices led to considerably higher prices for imports of steam and coking coal. Quarterly data on average steam coal prices, published by the International Energy Agency, indicate that the average price of coal imported to the European Union in the fourth quarter of 2004 (nominal dollars per ton) was up by 92 percent from the fourth quarter of 2002,^f and the average price of steam coal imported to Japan was up by 67 percent. For coking coal, the prices of imported coal to the European Union and Japan in the fourth quarter of 2004 were 60 and 54 percent higher, respectively, than in the fourth quarter of 2002. In late 2004, annual negotiations between Japanese steel mills and Australian coking coal producers established a new benchmark price for Japan's current fiscal year (ending on March 31, 2006) at \$113.40 per ton free-on-board (f.o.b.) port of exit, which was more than double the benchmark price of \$51.70 per ton for the previous year.^g

To date, higher coal prices do not appear to have had a significant effect on the demand for coal in international markets. In the electric power sector, the price of natural gas, coal's key competitor in this sector, has also been high. In the industrial sector, steel producers have seen increasing profits despite higher prices for coking coal and iron ore, as strong worldwide demand for steel has led to considerably higher prices for their products. As indicated, coal freight rates are expected to retreat some from recent high levels as new shipping capacity comes on line over the next few years. In turn,

(continued on page 60)

^aSSY Consultancy and Research Ltd., *SSY's Coal Trade Forecast*, Vol. 14, No. 2 (May 2005); and Energy Information Administration, *Quarterly Coal Report, October-December 2004*, DOE/EIA-0121(2004/4Q) (Washington, DC, March 2005), Tables 10, 12, and 14.

^b"Ocean Freight Rates Continue To Soar, Little Relief in Sight," *Coal Americas*, Energy Publishing LLC, No. 29 (November 3, 2003), p. 1.

^c"Steel/Iron Ore: Iron Ore Exports, Iron Ore Imports and Steel Production," *Monthly Shipping Review SSY* (April 21, 2005), p. 7.

^dGlobal Insight, Inc., *Global Coal Trade and Price Report (2004)* (Lexington, MA, December 2004), pp. xviii-xxii.

^e"Worsening Australian Coal Port Congestion," *Monthly Shipping Review SSY* (April 21, 2005), p. 4; and "Supply Dynamics on the Move," *Petroleum Economist* (October 6, 2004).

^fInternational Energy Agency, *Databases for Energy Prices and Taxes, 2nd Quarter 2005*, web site <http://data.iea.org>.

^gT. Grant-Taylor, "Coal Prices Steaming Ahead," *The Courier Mail* (February 7, 2005), p. 18; and S. Wyatt, "Coup for Coking Coal Exports," *Australian Financial Review* (December 13, 2004), p. 17.

Recent Developments in World Coal Trade (Continued)

this should lead to some downward pressure on the non-transportation component of the delivered price of coal in markets such as Europe, where Australian coal should again be able to compete with coal originating from South Africa and South America.

Along with strong growth in world coal trade in recent years, the geographical composition of coal supply for international markets has changed. While emerging

coal exporting countries such as China, Colombia, and Indonesia have increased their output substantially over the past few years, several of the more established coal-exporting countries such as the United States, South Africa, Canada, and Poland have seen their exports remain relatively constant or decline. Between 1998 and 2003, coal exports from China expanded by a substantial 190 percent, from 36 million tons to 103 million tons.^h

^hSSY Consultancy and Research Ltd, *SSY's Coal Trade Forecast*, Vol. 14, No. 2 (May 2005).

Despite South America's current foothold and expected gains in Europe, South Africa is projected to maintain its position as the leading supplier of coal to Europe throughout much of the forecast period. Currently, plans call for a 15-million-ton expansion of South Africa's Richards Bay Coal Terminal by the end of 2007, increasing the facility's annual throughput capacity to 95 million tons [54].

The Americas

Compared with European and Asian coal markets, imports of coal to North and South America are relatively small, totaling 77 million tons in 2003 (Table 9). Coal imports to the United States accounted for 32 percent of the 2003 regional total, followed by Canada at 30 percent and Brazil at 20 percent [55]. Most of the imports to Brazil were coking coal, and a majority of the remaining import tonnage was steam coal used for pulverized coal injection at steel mills [56].

Over the *IEO2005* forecast period, coal imports to the Americas are projected to increase by 29 million tons, with most of the additional tonnage going to the United States and Brazil. Coal imports to the United States are projected to increase from 25 million tons in 2003 to 46 million tons in 2025 [57]. This outlook is based on the capability and plans of existing coal-fired generating plants to import coal (primarily plants located on the eastern seaboard and in the southeastern part of the country) and announced plans to expand coal import infrastructure [58]. In Brazil, the country's expanding steel industry is projected to require increasing quantities of imported coal.

Partially offsetting the projected growth in coal imports elsewhere in the Americas, Canadian imports are expected to decline substantially over the next few years as the Ontario government moves ahead with the shutdown of the Province's five coal-fired generating plants. Ontario imported 20 million tons of coal in 2003, primarily from U.S. coal mines in Central Appalachia and the Powder River Basin [59]. After Ontario, Nova Scotia and

New Brunswick account for most of Canada's remaining import tonnage. In 2003, Nova Scotia imported 2.0 million tons of coal and New Brunswick imported 1.4 million tons. U.S. coal exports to Canada are projected to fall from 21 million tons in 2003 to 7 million tons in 2025 [60].

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